

## TITLE

### MANUFACTURING METHOD FOR AN ELECTRON-EMITTING SOURCE OF TRIODE STRUCTURE

5

## BACKGROUND OF THE INVENTION

### Field of the Invention

10 The present invention relates in general to a manufacturing method for an electron-emitting source. In particular, the present invention relates to a manufacturing method for an electron-emitting source of triode structure.

### Description of the Related Art

15 The method of manufacturing an electron-emitting source using carbon nanotubes (CNT) as an emitter is already widely used in the field of FED (field emission display) diode structure. However, in the field of the CNT-FED of triode structure, it is very difficult to coat the CNT on the negative electrode because  
20 the gate hole in the above triode structure is smaller than 100  $\mu\text{m}$ . Therefore, it is very important to find an improved method to accurately coat the CNT on negative electrode.

25

## SUMMARY OF THE INVENTION

The present invention is intended to overcome the above-described disadvantages.

30

Therefore, the first object of the present invention is to provide a manufacturing method for an electron-emitting source of triode structure, comprising the steps of forming a cathode

layer on a substrate, forming a dielectric layer on the cathode layer, and positioning an opening in the dielectric layer to expose the cathode layer wherein the opening has a surrounding region and forming a gate layer on the dielectric layer, except  
5 on the surrounding region, forming a hydrophilic layer in the opening, forming a hydrophobic layer on the gate layer and the surrounding region wherein the hydrophobic layer contacts the ends of the hydrophilic layer, dispersing a carbon nanotube solution on the hydrophilic layer using ink jet printing; and  
10 executing a thermal process step, and removing the hydrophobic layer.

According to the present invention as described above, carbon nanotubes are accurately deposited over a large area using ink jet printing.

The second object of the present invention is to provide a manufacturing method for an electron-emitting source of triode structure, comprising the steps of forming a cathode layer on a substrate, forming a dielectric layer on the cathode layer, and positioning an opening in the dielectric layer to expose the  
15 cathode layer, wherein the opening has a surrounding region, forming a gate layer on the dielectric layer, except on the surrounding region, forming a sacrificial layer on the gate layer and the surrounding region, wherein the opening and the cathode layer are exposed, dispersing a carbon nanotube solution  
20 in the opening using screen printing, executing a thermal process step, and removing the sacrificial layer.

According to the present invention as described above, carbon nanotubes are successfully deposited over a large area using screen printing.

The third object of the present invention is to provide a manufacturing method for an electron-emitting source of triode structure, comprising the steps of forming a cathode layer on a substrate, forming a dielectric layer on the cathode layer, and positioning an opening in the dielectric layer to expose the cathode layer, wherein the opening has a surrounding region, forming a gate layer on the dielectric layer, except on the surrounding region, forming a carbon nanotube photoresist layer on the gate layer and covering the opening using spin coating, and patterning the carbon nanotubes photoresist layer in a predetermined pattern, and executing a thermal process step.

According to the present invention as described above, carbon nanotubes are successfully deposited over a large area using spin coating.

The fourth object of the present invention is to provide a manufacturing method for an electron-emitting source of triode structure, comprising the steps of forming a cathode layer on a substrate forming a dielectric layer on the cathode layer, and positioning an opening in the dielectric layer to expose the cathode layer, wherein the opening has a surrounding region, forming a gate layer on the dielectric layer, except on the surrounding region, forming a sacrificial layer on the gate layer and the surrounding region, wherein the opening is exposed, forming an adhesive layer in the opening, forming a carbon nanotube layer on the adhesive layer using an electrophoretic deposition step, executing a thermal process step, and removing the sacrificial layer.

According to the present invention as described above, carbon nanotubes are accurately deposited over a large area using electrophoretic deposition (EPD).

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reading the subsequent detailed description in conjunction with the examples and references made to the accompanying drawings, wherein:

Figs. 1a to 1h are sectional views showing a process for manufacturing an electron-emitting source of triode structure in accordance with embodiment 1 of the present invention;

Figs. 2a to 2h are sectional views showing a process for manufacturing an electron-emitting source of triode structure in accordance with embodiment 2 of the present invention;

Figs. 3a to 3h are sectional views showing a process for manufacturing an electron-emitting source of triode structure in accordance with embodiment 3 of the present invention;

Figs. 4a to 4g are sectional views showing a process for manufacturing an electron-emitting source of triode structure in accordance with embodiment 4 of the present invention; and

Figs. 5a to 5c are sectional views showing cathode electrophoretic deposition, anode electrophoretic deposition, and suspending electrophoretic deposition respectively.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

### Embodiment 1

Figs. 1a to 1h are sectional views showing a process for manufacturing an electron-emitting source of triode structure using ink jet printing.

First, as shown in Fig 1a, a substrate 10 is provided. Secondly, as shown in Fig 1b, a cathode layer 12 is deposited on the substrate 10. Further, as shown in Fig 1c, a dielectric

layer 14 is deposited on the cathode layer 12, and an opening 13 is positioned in the dielectric layer 14 to expose the cathode layer 12, wherein the opening 13 has a surrounding region 15. Furthermore, as shown in Fig 1d, a gate layer 16 is deposited on the dielectric layer 14 except the surrounding region 15. a gate hole 17 is formed after depositing the gate layer 16.

As shown in Fig 1e, a hydrophilic layer 18 is deposited in the gate hole 17. Because the hydrophilic layer 18 absorbs the water of a carbon nanotube solution used in this embodiment, it successfully prevents the CNT solution from overflowing the gate hole 17.

As shown in Fig 1f, a hydrophobic layer 20 is deposited on the surface of the gate layer 16 and the surrounding region 15, wherein the hydrophobic layer 20 contacts the ends of the hydrophilic layer 18. Because the hydrophobic layer 20 defines the position where CNT solution formed on the cathode layer 12 and prevents CNT solution from being absorbed into the sidewalls of the gate hole 17, it successfully solves the leakage current or short problems caused by the residue of the CNT solution between the cathode layer 12 and the gate layer 16 after thermal process step.

As shown in Fig 1g, a CNT solution 22 is dispersed on the hydrophilic layer 18 using ink jet printing. Finally, a thermal process step is executed, and the hydrophobic layer 20 is removed to form a CNT emitter 24, as shown in Fig 1h.

As mentioned above, according to embodiment 1 of the present invention, carbon nanotubes are accurately deposited over a large area using ink jet printing, and an electron-emitting source of triode structure having good properties, and used as CNT-FED, is obtained.

The substrate 10 is preferably made of glass. The cathode layer 12 or the gate layer 16 is preferably composed of electric conductors such as silver. The hydrophobic layer 20 is preferably composed of hydrophobic materials such as hydrophobic photoresist. The above thermal process preferably adopts a sintering step.

#### Embodiment 2

Figs. 2a to 2h are sectional views showing a process for manufacturing an electron-emitting source of triode structure using screen printing.

First, as shown in Fig 2a, a substrate 30 is provided. Secondly, as shown in Fig 2b, a cathode layer 32 is deposited on the substrate 30. Further, as shown in Fig 2c, a dielectric layer 34 is deposited on the cathode layer 32, and an opening 33 is positioned in the dielectric layer 34 to expose the cathode layer 32, wherein the opening 33 has a surrounding region 35. Furthermore, as shown in Fig 2d, a gate layer 36 is deposited on the dielectric layer 34 except the surrounding region 35. a gate hole 37 is formed after depositing the gate layer 36.

As shown in Fig 2e, a sacrificial layer 38 is deposited on the surface of the gate layer 36 and the surrounding region 35, wherein the gate hole 37 and the cathode layer 32 are exposed. Because the sacrificial layer 38 defines the position where the CNT solution is formed on the cathode layer 32, and prevents CNT solution from being absorbed into the sidewalls of the gate hole 37 or the surface of the gate layer 36, it successfully solves the leakage current or short problems caused by the residue of the CNT solution on the cathode layer 32 or the gate layer 36 after thermal process step.

As shown in Fig 2f, a CNT solution 40 is dispersed on the gate hole 37 by screen mask 42 using screen printing. At this time, some residue 43 of the above CNT solution is dropped on the surface of the sacrificial layer 38. In this case, the residue 43 is removed using a polish step, as shown in Fig 2g. Finally, a thermal process step is executed, and the sacrificial layer 38 is removed to form a CNT emitter 44, as shown in Fig 2h.

As mentioned above, according to embodiment 2 of the present invention, carbon nanotubes are accurately deposited over a large area using screen printing, and an electron-emitting source of triode structure having good properties, and used as CNT-FED, is obtained.

The substrate 30 is preferably made of glass. The cathode layer 32 or the gate layer 36 is preferably composed of electric conductors such as silver. The sacrificial layer 38 is preferably composed of photosensitive materials such as photoresists, peelable materials such as hydrophilic materials and lipophilic materials, soluble materials, sinterable materials, or etchable materials. The above thermal process preferably adopts a sintering step.

### Embodiment 3

Figs. 3a to 3h are sectional views showing a process for manufacturing an electron-emitting source of triode structure using spin coating.

First, as shown in Fig 3a, a substrate 50 is provided. Secondly, as shown in Fig 3b, a cathode layer 52 is deposited on the substrate 50. Further, as shown in Fig 3c, a dielectric layer 54 is deposited on the cathode layer 52, and an opening 53 is positioned in the dielectric layer 54 to expose the cathode

layer 52, wherein the opening 53 has a surrounding region 55. Furthermore, as shown in Fig 3d, a gate layer 56 is deposited on the dielectric layer 54 except the surrounding region 55. a gate hole 57 is formed after depositing the gate layer 56.

5 As shown in Fig 3e, a carbon nanotube photoresist layer 58 is deposited on the gate layer 56 and covering the gate hole 57 using spin coating. The carbon nanotube photoresist layer 58 is preferably composed of positive photoresist or negative photoresist. In this case, the carbon nanotube photoresist layer  
10 58 is composed of negative photoresist and the CNT solution. Furthermore, as shown in Figs 3f to 3g, a CNT emitter pattern 62 is exposed by mask 60 using ultraviolet light and then patterned. In this case, the opening width of the mask 60 is smaller than the width of the gate hole 57 in order to prevent the patterned CNT emitter pattern 62 from contacting the gate  
15 layer 56 to prevent short problem. Finally, a thermal process step is executed to form a CNT emitter 64, as shown in Fig 3h.

As mentioned above, according to embodiment 3 of the present invention, carbon nanotubes are accurately deposited over a large area using spin coating, and an electron-emitting source of triode structure having good properties, and used as CNT-FED, is obtained.  
20

The substrate 50 is preferably made of glass. The cathode layer 52 or the gate layer 56 is preferably composed of electric  
25 conductors such as silver. The above thermal process preferably adopts a sintering step.

#### Embodiment 4

Figs. 4a to 4h are sectional views showing a process for manufacturing an electron-emitting source of triode structure using electrophoretic deposition (called EPD).  
30



First, as shown in Fig 4a, a substrate 70 is provided. Secondly, as shown in Fig 4b, a cathode layer 72 is deposited on the substrate 70. Further, as shown in Fig 4c, a dielectric layer 74 is deposited on the cathode layer 72, and an opening 73 is positioned in the dielectric layer 74 to expose the cathode layer 72, wherein the opening 73 has a surrounding region 75. Furthermore, as shown in Fig 4d, a gate layer 76 is deposited on the dielectric layer 74 except the surrounding region 75. a gate hole 77 is formed after depositing the gate layer 76.

As shown in Fig 4e, a sacrificial layer 78 is deposited on the surface of the gate layer 76 and the surrounding region 75, wherein the gate hole 77 and the cathode layer 72 are exposed. Because the sacrificial layer 78 defines the position where CNT formed on the cathode layer 72, and prevents CNT from being absorbed into the sidewalls of the gate hole 77 or the surface of the gate layer 76 during electrophoretic deposition step, it successfully solves the leakage current or short problems caused by the residue of the CNT left on the dielectric layer 74 or the gate layer 76 after thermal process step.

As shown in Fig 4f, an adhesive layer 80 is deposited in the gate hole 77. Further, CNT is deposited on the adhesive layer 80 using an electrophoretic deposition step. In this case, the electrophoretic deposition preferably adopts cathode electrophoretic deposition, anode electrophoretic deposition, or suspending electrophoretic deposition.

Fig. 5a is a sectional view showing cathode electrophoretic deposition. In this Fig. 5a, 90 and 94 show a metal electrode and an organic solvent system, respectively. Because of a cathode layer 72 is connected with negative electrode, a positive CNT particle 92 is attracted to deposit on the adhesive

layer 80. Further, Fig. 5b is a sectional view showing anode electrophoretic deposition. In this case, because the cathode layer 72 is connected with positive electrode, the negative CNT particle 92 is attracted to deposit on the adhesive layer 80. Fig. 5c is a sectional view showing suspending electrophoretic deposition. Water solution system 96 preferably uses distilled water or deionized water as solvent, neither of which interact with sacrificial layer 78.

Lastly, a thermal process step is executed, and the sacrificial layer 78 is removed to form a CNT emitter 82, as shown in Fig 4g.

As mentioned above, according to embodiment 4 of the present invention, carbon nanotubes are accurately deposited over a large area using electrophoretic deposition, and an electron-emitting source of triode structure having good properties, and used as CNT-FED, is obtained.

The substrate 70 is preferably made of glass. The cathode layer 72 or the gate layer 76 is preferably composed of electric conductors such as silver. The sacrificial layer 78 is preferably composed of photosensitive materials such as photoresists, peelable materials such as hydrophilic materials and lipophilic materials, soluble materials, sinterable materials, or etchable materials. The above thermal process preferably adopts a sintering step.

Finally, while the invention has been described by way of example and in terms of the preferred embodiment, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements as would be apparent to those skilled in the art. Therefore, the scope of the appended

claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

2